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ABSTRACT

This paper argues that research findings from the study of teaching could be very useful in enhancing knowledge and tools for the design of both conventional and intelligent instructional software. It also suggests that if the ways in which teachers effectively conduct instruction are different and in certain ways better than other media, and if teachers and computers share the critical capabilities of intelligent information processing, then two things may be predicted: (1) the study of instruction, if limited to instruction delivered by non-intelligent instruments, would not include research and theory regarding what to do with an intelligent instructional instrument; and (2) the study of teaching, being devoted to instruction delivered by intelligent entities, should include research and theory regarding what to do with an intelligent instructional instrument--the computer. A survey of research in the study of teaching uncovered the following names: David Berliner, N. L. Gage, Philip Hosford, Christopher Clark, Robert Yinger, Barak Rosenshine, and Madeline Hunter. Topics and key ideas found to be repeated and emphasized as major areas of interest were teacher effectiveness, teacher thinking, and models of teaching. This survey, however, did not reveal prescriptively-oriented theories and models of what effective teachers do and how they do it, nor were analyses found of the nature of interaction, questioning, and feedback. It is suggested that instructional technologists may have to study teachers and teaching themselves to obtain the information they will need to establish protocols for their "automated teachers." A list of references is provided. (JB)

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Instructional Strategies in CAI:
Instructional Design Theory Needs

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Introduction

There should be no doubt in any of our minds that the computer is a useful medium of instruction and that it is potentially an unusually powerful medium. We would also all agree, I think, that our knowledge of what to do with the computer in instruction is less than perfect. I do not believe that there exists a body of prescriptive knowledge which tells us how to make best use of the computer's unique instructional medium characteristics when designing instruction which will be delivered by a computer. I will go further and assert that we don't even know much at all about instructional design that takes advantage of what a computer can do best. This paper will explore one avenue for new research and development in instruction: use of insights from the study of teaching for development of intelligent instructional software.

Computers, Teachers, and Other Media

I believe that a computer is more like a person than it is like other machines with regard to its instructional medium attributes. "With the exception of the teacher, no other delivery system equals the computer in its potential to accommodate the needs of the individual learner." (Carrier, 1985, p. 155) Although it is unusual

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to perform an instructional medium attributes analysis of human beings, it is possible to do so, as I did in 1982, albeit somewhat tongue in cheek. (Ragan, 1982) When a human is used in the role of an instructional instrument, we call that instrument a "teacher." This use of humans is so time-honored and commonplace that we do not even consider these units called "teachers" as instructional instruments at all, rather thinking of these "teachers" as one major means of delivery of instruction and everything else being either "instructional instruments" or "aids" to a teacher.

There are many attributes of a human which may help make him or her be a good instructional device, and there are also many attributes which make a teacher less than ideal. For example, humans are notoriously poor at being able to do something on one day in exactly the same way they were able to do it a year or even a day previously. This lack of repeatability makes teacher delivery so unreliable that it is at times difficult to understand how the use of "teachers" could possibly be as popular as they are in schools, disregarding their expense and other drawbacks.

The reason why the use of "teachers" is mandatory in not only schools but also training settings can be boiled down, I believe, to their enormously powerful information processing abilities. Although not perfect by any means (humans, for example, have a severely limited capacity for temporary information storage), humans have an incredible capability in their ability to do what they call "interact" based on information processing. Consider this: a human can receive what a student says or writes in natural language (this is called "listening" and "reading"), process that information (with humans, they call that "thinking"), and can ask a question or provide some other stimulus which is based upon what the student said or wrote.

Like the human, a computer's primary enviable attribute in instruction is information processing ability. Were it not for that, a computer would be a poor alternative for a text book with regard to legibility, a poor alternative to 35mm slides or an overhead projector with regard to graphic display, and a poor alternative to film and video with regard to providing animation. Although there are ways to improve a computer's performance in all of these areas, we don't use computers due to their fabulous display capabilities. We use computers because of their information processing capabilities.

When we try to use a computer in a manner like that which older media such as text, video, or programmed instruction could deliver--the automatic-page-turner sort of CAI--our efforts may be met with success in terms of student learning but we find we are open to scathing criticism for not making use of the computer's capabilities. And, regardless of whether other people criticize us or not, we know that all we have accomplished is to provide effective instruction in an area which can be provided with equal effectiveness through other means while, at the same time, topics abound within our curriculum which are veritable killers--learning tasks which only the most advantaged students fully master, leaving the remainder of the class--which in many cases is the majority--with limited success or complete confusion. It is these topics, the killers, that remind us that computers are supposed to be wonderful instructional instruments. But as we conceive of computer-delivery of instruction which is further and further from that which may be delivered by text, video, or programmed instruction, we find ourselves as instructional

designers conceptually further and further away from anything we know much about.

If it is true, as I am saying, that we get further and further from the center of our base of knowledge and tools in instructional design when we attempt to design instructional software which makes effective use of the computer's unique attributes, what field of knowledge, if anything, might we find ourselves getting closer and closer to? Recall that earlier we noted an instructional medium which resembled computers in that its strength lay in ability to process information--the use of humans or "teachers." There is a field of study related to that one approach to the delivery of instruction and that field is called "the study of teaching."

The Study of Teaching and the Study of Instruction

The study of teaching is considerably separate from the study of instruction. A good general term for what most of our research in instructional technology relates to is "the study of instruction." But the research and theory interests of a teacher-educator or a professor of Elementary Education or of Teaching Methods in a subject area such as mathematics, language arts, reading, or social studies, will most likely be in the area and traditions of the study of teaching (not the study of instruction). Your colleague whose primary umbrella professional organization is not AECT but is ASCD (Association for Supervision an Curriculum Development) and who always has a difficult time understanding what it is that you actually do will probably have a primary background and interest in teaching research. By the same token, it is fair to say, I believe, that you have an equally difficult time understanding what that colleague does.

My conclusion from the above this: if the ways in which teachers effectively conduct instruction are different and in certain ways better than other media, and if teachers and computers share the critical capabilities of intelligent information processing, then two things may be predicted:

1. that the study of instruction, being devoted in the main to instruction delivered by non-intelligent instruments, would not include research and theory regarding what to do with an intelligent instructional instrument, and
2. that the study of teaching, being devoted in the main to instruction delivered by intelligent entities (humans), should include research and theory regarding what to do with an intelligent instructional instrument, the computer.

Artificial Intelligence and Instructional Design

My interest in the current topic did not begin with artificial intelligence (AI), but I have realized over the past year that a concern with teaching research in the context of instructional design for CAI, would lead quite naturally into contributions toward design of **intelligent instructional software.** Although I see little recognition of it in our literature as of yet, AI methods and techniques have already been developed which have enormous potential in instruction, (Schank, 1984) and there is good reason to believe that education, specifically the delivery of instruction, will be one of the most important uses of AI in the near future. "Automated,

intelligent, individual instructors are one of the most interesting and socially significant possible applications of AI." (Schank, 1984, p. 205) Although the potentials appear to be enormous, and a number of people have noted to me their interest in the area, it does not appear that anyone knows much about design of what I will call "intelligent instructional software" or "IIS." Not only do we instructional technologists know little about IIS design, our counterparts in computer science appear equally unready. For example, Roger Schank, whose work in artificial intelligence at Yale University is discussed in The Cognitive Computer (Schank, 1984), appears as naive about instruction as anyone could possibly be in his discussions of uses of artificial intelligence in instruction. For example,

> If today's teachers were watching each child carefully, they could vary the complexity and amount of the examples in the books so that each child could maintain interest according to his progress. If workbooks were smart enough they could do this by themselves. But workbooks don't know whether or not a child is doing the exercises correctly, or how far he has gone. A workbook isn't able to stop him in the middle of page 54, exercise D, problem 13, and say, No, you've missed something, let's go back to that tricky problem on page 50. Nor can it say Great! You've got the hang of it. Let's go on to something else. Think of how alienating and dehumanizing the grade-school textbooks and the instruction that is coordinated with them really are. (Schank, 1984, p. 207)

One gets the impression that if left to their own devices, the computer science/AI community will do little more than re-discover programmed instruction, not going quite as far as re-discovery of instructional design.

In studying instructional strategies in CAI and in thinking about questions of the design of IIS, I became convinced that research findings from the study of teaching could be of enormous utility in enhancing our knowledge and tools for design of instructional software, both conventional and intelligent. Based upon this conviction I therefore set out to survey the research and theory in the area of the study of teaching. (Footnote: in this effort I am indebted to Prof. John F. Wedman, University of Northern Iowa, and to Jo Lynn Digranes, doctoral student in educational technology at the University of Oklahoma for their suggestions and ideas.) Rather than attempt a full summary of the literature in the study of teaching--an impossible task in this setting in any event--I would like to present to you the highlights of what I found, recalling if you will that I was looking for help in the design of instructional software.

The Study of Teaching in a Nutshell

The people's names I found most cited and recommended, and therefore whose writing I concentrated on in my survey were: David Berliner, Philip Hosford, Christopher Clark, Robert Yinger, Barak Rosenshine, N.L. Gage, and Madeline Hunter. Topics and key ideas within the study of teaching which I found most repeated and emphasized as major areas of interest were: teacher effectiveness,

teacher thinking, and models of teaching. Of all the material which I read, I would recommend as a single most helpful source, Using What We Know About Teaching, Edited by Philip Hosford and published by the ASCD. (Hosford, 1984)

The following areas were used as primary organizing topics by Berliner in his discussion of the status of teaching research (Berliner, 1984):

A. Pre-instructional factors
   1. Content decisions
   2. Time allocation decisions
   3. Policy decisions
   4. Grouping decisions
   5. Decisions about activity structures

B. During-instruction factors
   1. Engaged time
   2. Time management
   3. Monitoring success rate
   4. Academic learning time
   5. Monitoring
   6. Structuring
   7. Questioning

C. Climate factors
   1. Communicating academic expectations for achievement
   2. Developing a safe, orderly and academically-focused environment for work
   3. Sensible management of deviancy
   4. Developing cooperative learning environments

D. Post-instructional factors
   1. Tests
   2. Grades
   3. Feedback

The content of most of the topics is descriptive in nature. For example, with regard to content decisions, the research indicates that the factor exists; in other words, that teachers do in fact make content decisions from time to time. The research does not speak to how teachers make content decisions or how best content decisions should be made.

Berliner's summary emphasized for many topics that there is a great amount of variability among teachers. This was the primary finding summarized for time allocation decisions, for policy decisions, and for activity structures.

For the remainder of the topics, the primary findings noted can be characterized by "performance of this function is correlated with student learning" or by "teachers who do this more than most teachers have students who achieve more than average." For example, studies are cited which indicate that there is a strong relationship between success rate (how often the learner is successful on things like exercises, problems, and so forth) and achievement. Rather than note the utility of instructional instruments such as programmed instruction in this regard, the a typical conclusion for teaching

research is drawn: "It appears that the classroom in which the teacher moves rapidly about, monitoring students and raising the number of substantive interactions with students, is the class where students do well." (Berliner, 1984, p. 62) "A substantive interaction between a teacher and student takes place when the teacher checks to see if the student is doing things correctly, asks questions, gives the student academic feedback, and so on." (p. 62-63) Both tutorial CAI and programmed instruction do this sort of thing routinely. In one sense, we can turn this area into a design recommendation, albeit not too innovative one: "CAI software should be designed so that it checks student work for accuracy, that it asks questions, and that it provide feedback." On the other hand, a question presents itself for which we do not have a ready answer: what difference does it make to have a **human** do these things? If it is the case that a human is needed, what are the critical variables? Are there particular behaviors that only humans can produce (at present)? If so, an expert system protocol analysis of teacher monitoring behaviors would appear needed if we are going to get into AI in instruction. Or is the critical factor not what the teacher does but what the teacher is: a person. If that is the case, in what regard does the student's knowledge that the teacher is a person make a difference?

In another review, Hosford (1984) summarizes the "science" of teaching to be found in five factors:

T - time on task (sufficient amount)
E - expectations (projection of high expectations for learning)
M - monitoring student progress
P - problems assigned (individual work which can be done individually)
O - organization (manage class so well that discipline is not a problem)

The "art of education" is seen in teacher's fostering and characterization of what Hosford calls the "silent curriculum"--four broad areas, three of which are ignored by a school's manifest curriculum, but associated with greatness in teaching:

1. desire for learning
2. improved self-concept
3. respect for others
4. skill in the use of the 3 R's

Teachers who can impart in students a desire for learning, who contribute to improvements in their students' self-concepts, who show a respect for others and teach their students to do so, and who are themselves highly skilled in the basics and improve their students' achievement in the basics are what Hosford would characterize as being "high art" teachers. Teachers who are good with regard to behaviors within the "science" domain he would characterize as "high science." The best teaching would be both high art and high science.

Are Hosford's factors the sorts of things we can employ in design of intelligent instructional software? Although Hosford's factors are quite broad, perhaps they--even the "art of education" factors--are areas in which we can begin some productive work. If, for example,

one were to perform a protocol analysis of teaching, where would one start? It seems only reasonable that if we want to develop principles for intelligent instructional software, that we should begin by focusing investigations on the areas within which the most is known and which are considered most important by the people whose field is research into the phenomena which we wish to model.

In another review, Bauman (1984) cites nine factors of teacher effectiveness, reminiscent of those we have already seen:

1. clear goals and objectives
2. allocated time
3. academic engaged time
4. success rates
5. management
6. monitoring
7. direct instruction (the provision of)
8. instructional organization
9. classroom atmosphere

Similarly, Rosenshine (1983) provides six functions, from six studies of teacher effectiveness, which describe what effective teachers do:

1. review and checking previous day's work
2. presenting new content/skills
3. initial student practice (and checking for understanding)
4. feedback and correctives (and re-teaching if necessary)
5. student independent practice
6. weekly and monthly reviews

Clark and Yinger (1977) reviewed research on teacher thinking. This work, quite different from the work on teacher effectiveness, may be relevant to requirements and specifications for intelligent instructional software. One major question addressed by the research on teacher thinking is that of interactive decision-making. It had been assumed that teachers do a great deal of decision-making on their feet, as it were, in the classroom. The research indicates that they do, but not much. Teachers consider alternative strategies only when things are going poorly. In other words, teachers apparently do not make efforts to optimize learning. Student participation and involvement are the primary cues used by the teacher, and, in fact, teachers rarely change their strategy.

Another facet of the teacher thinking research reviewed by Clark and Yinger is the content of teachers' "interactive thoughts." (p. 294) Teachers apparently think about present, past, and future issues while interacting with students. Teacher thoughts about the present are primarily about student behavior and their own affective state. Teacher thoughts about the past are concentrate on reflection on past events within the present lesson, retrieval of factual information such as personal information about particular students, curriculum content, principles of teaching, and beliefs about children (learner characteristics). Finally, teacher thoughts about the future are primarily on tactics to be used next in the current lesson, predictions or visualizations of directions the lesson might take, and

expectations for student behavior and student learning of objectives.

The research on teacher thinking may be a good place to begin when determining information processing requirements and structures for AI-based intelligent instructional software.

Finally, I would like to present a key point or two from an individual study rather than a review. The study, Yinger (1980), was a single-subject study of teacher planning. The aspect of the study which I found of most interest was the investigator's report of the teacher's use of "routines." These "teaching routines" were mechanisms used to establish and regulate activities and to simplify planning. Four types of routines emerged: 1. activity routines, 2. instructional routines, 3. management routines, and 4. executive planning routines. These teacher routines appear to have, at a superficial level at least, a close correspondence to general-level computer system activity descriptions.

Conclusions from Teaching Research

When I began my survey of teaching research, I had hoped that I would find prescriptively oriented theories and models of what effective teachers do and how they do it, similar to instructional design theories and models but with reference to teachers rather than materials or systems. I hoped, particularly, to find analyses of the nature of interaction, questioning, and feedback. I did not find what I hoped for. Although I do not claim my survey of teaching research reviews to be an in-depth review itself, I think this survey fairly grasps the nature and quality of the mainstream of recent research on teaching. Perhaps another survey of the research on teaching should be performed, this one not focusing on the recent research but on finding useful information in what appear to be areas of most potential: interaction, questioning, and feedback.

I have noted earlier, while discussing various reviews, that the possibility exists of using some of the work reviewed as a beginning point for protocol analysis for development of expert systems. I would like to expand that idea and suggest that instructional researchers may wish to begin to study teaching themselves. This new study of teaching would build upon the existing literature but would proceed along new directions. In other words, if what we need isn't there, we may have to do it ourselves. We will have to study teachers and teaching to establish protocols for our "automated teachers." In so doing, we will not only need to begin where the current work leaves off (rather than painfully rediscover the wheels of teaching research) but also we may find the skills and perspective of seasoned teaching researchers to be invaluable.

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